Discussion on Unsteady RANS

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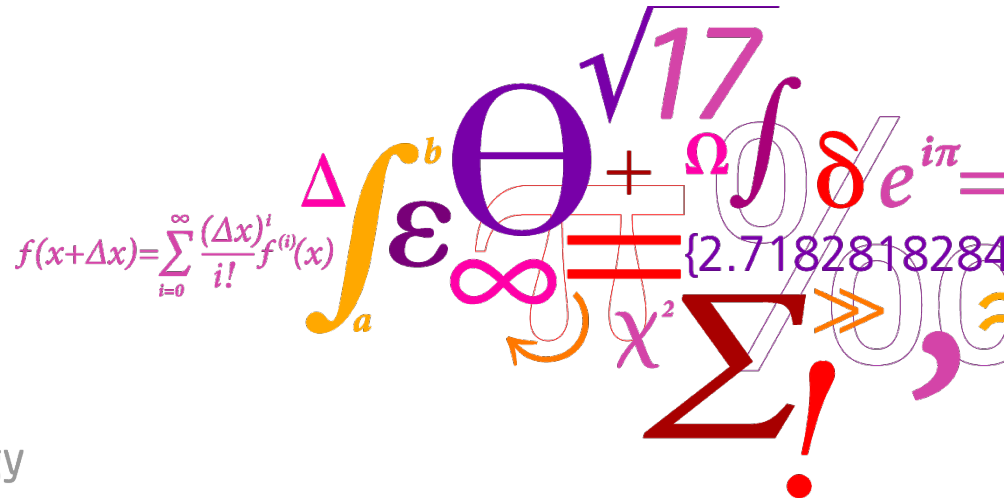

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Neutral Atmospheric Boundary Layer (ABL)

'Standard $k-\epsilon$ model

$$\frac{\delta}{\delta t}(\rho k)+\frac{\delta}{\delta x_j}(\rho U_j k)=\frac{\delta}{\delta x_j}\left[\left(\mu+\frac{\mu_T}{\sigma_k}\right)\frac{\delta k}{\delta x_j}\right]+P-\rho\varepsilon$$

$$\frac{\delta}{\delta t}(\rho \varepsilon)+\frac{\delta}{\delta x_j}(\rho U_j \varepsilon)=\frac{\delta}{\delta x_j}\left[\left(\mu+\frac{\mu_T}{\sigma_s}\right)\frac{\delta \varepsilon}{\delta x_j}\right]+C_{\varepsilon 1}\frac{\varepsilon}{k}P-C_{\varepsilon 2}\rho\frac{\varepsilon^2}{k}$$

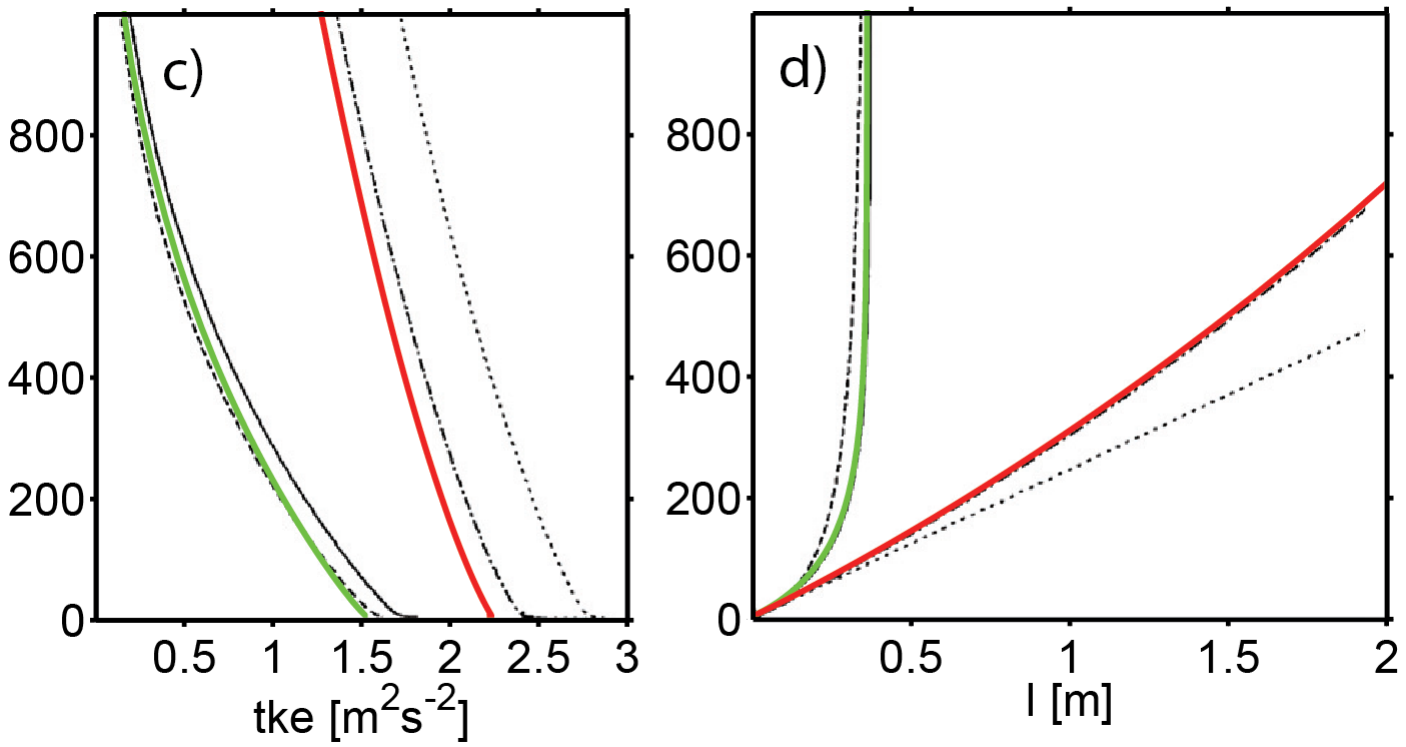
Length-Scale limiter of Apsley & Castro (1997):

$$l=C_\mu^{3/4}\frac{k^{3/2}}{\varepsilon},$$

$$C_{\varepsilon 1}^{*}=\left[C_{\epsilon 1}+(C_{\epsilon 2}-C_{\epsilon 1})\frac{l}{l_{max}}\right]$$

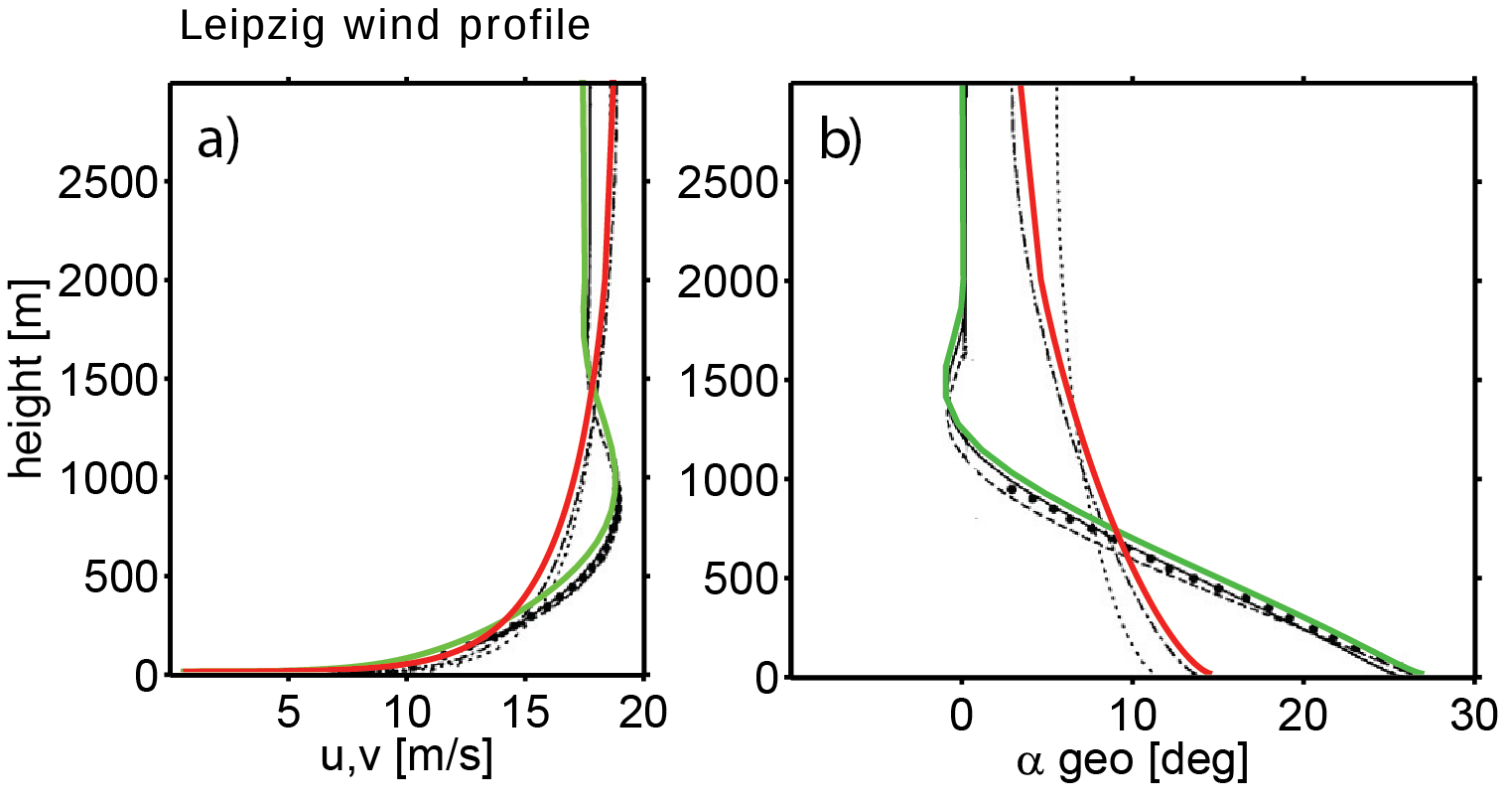
Neutral Atmospheric Boundary Layer (ABL)

The length scale limiter, limits the length scale …



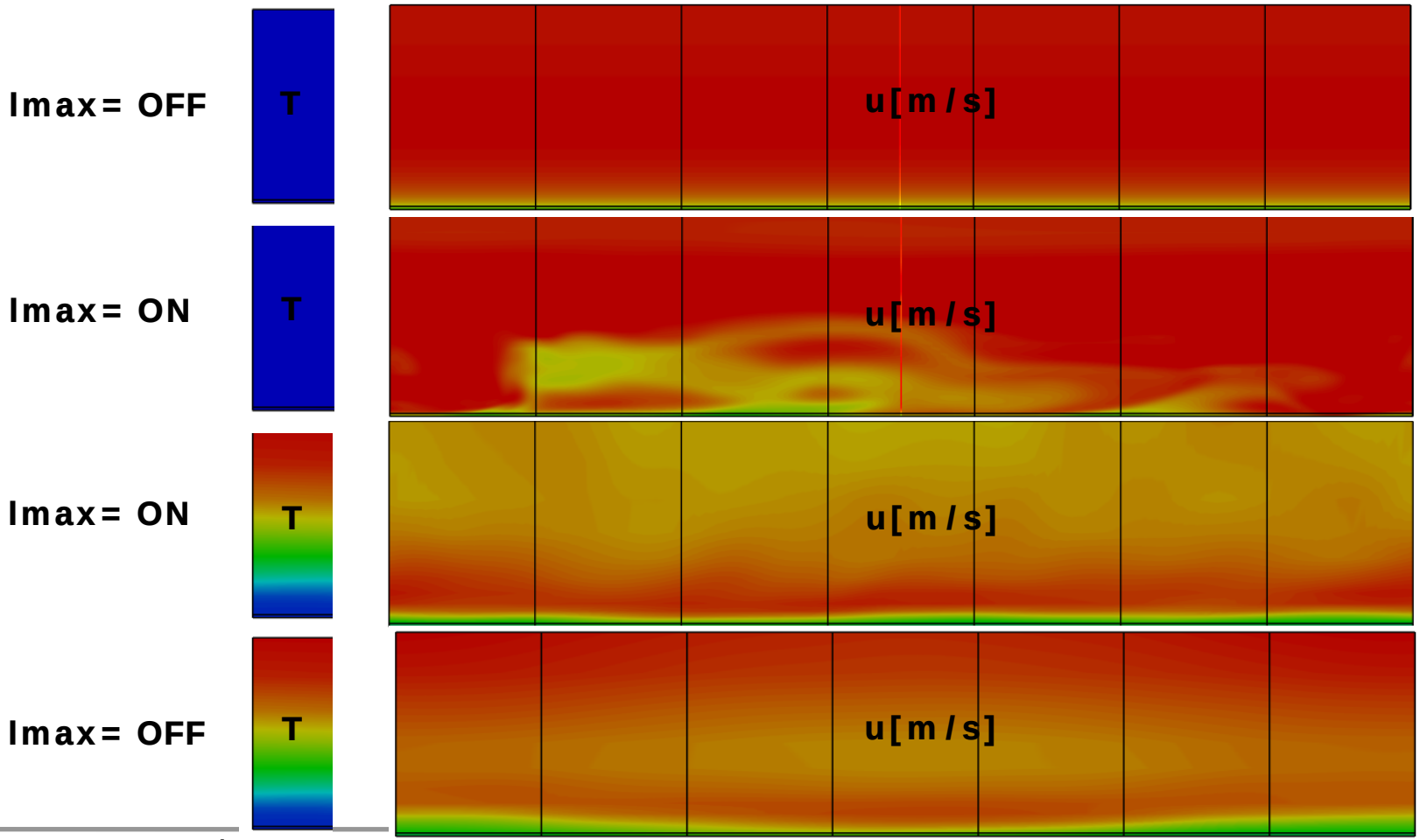
Neutral Atmospheric Boundary Layer (ABL)

… and improves results …



Neutral Atmospheric Boundary Layer (ABL)

... and causes problems!



What causes these problems?

LES and RANS-equations are the same!

Momentum equations for an incompressible Newtonian fluid:

$$\frac{\partial u_i}{\partial t} + \frac{\partial (u_i u_j)}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \nu \frac{\partial^2 u_i}{\partial x_j^2} + f_i$$

RANS- and LES-equations written in same form
… different only by how stress term is modelled

Compo solved parts:

$$u_i = \overline{u}_i + \tilde{u}_i$$

Momentum equations for resolved motions:

$$\frac{\partial \overline{u}_i}{\partial t} + \frac{\partial (\overline{u}_i \overline{u}_j)}{\partial x_j} = -\frac{\partial \overline{p}}{\partial x_i} + \frac{\partial \tilde{\tau}_{ij}}{\partial x_j} + \overline{f}_i$$

turbulence model, equation

Turbulent stresses: product of fluid strain and **eddy-viscosity:**

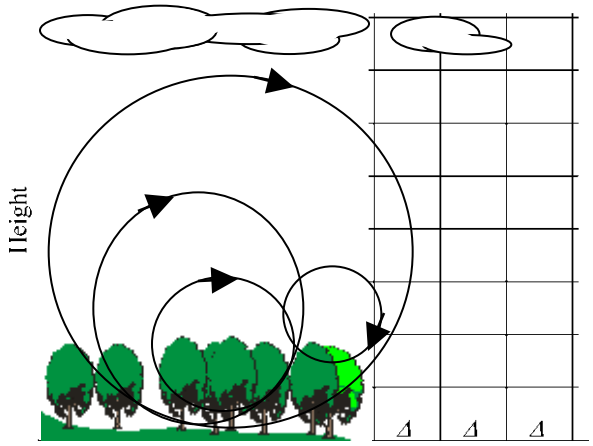
$$\tilde{\tau}_{ij} = \nu_T \left(\frac{\partial \overline{u}_i}{\partial x_j} + \frac{\partial \overline{u}_j}{\partial x_i} \right) + \frac{\delta_{ij}}{3} \tilde{\tau}_{kk}$$

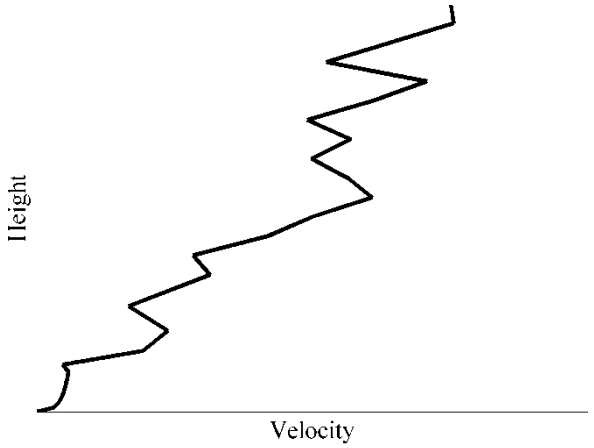
$$\nu_T = length \cdot velocity$$ ‘Standard‘ eddy-viscosity model

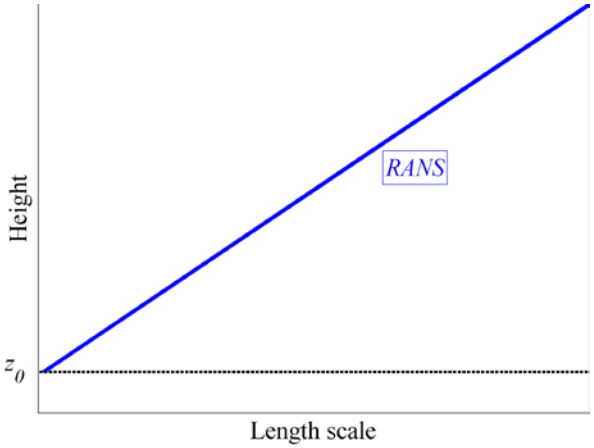
$$\nu_T = \frac{\tilde{k}^{3/2}}{\tilde{\epsilon}} \cdot \tilde{k}^{1/2}$$ ‘Standard‘ $k-\epsilon$ RANS model

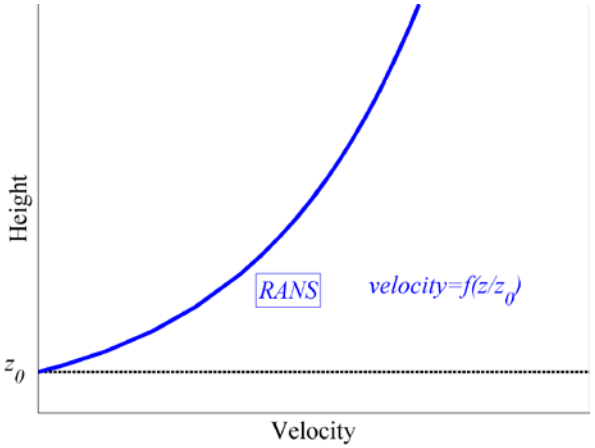
$$\nu_T = C_\Delta \Delta \cdot \tilde{k}^{1/2}$$ ‘Standard‘ $k-$ LES model

turbulence model, illustration

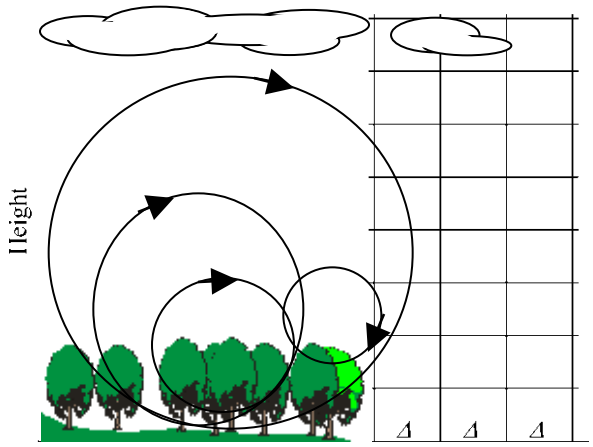


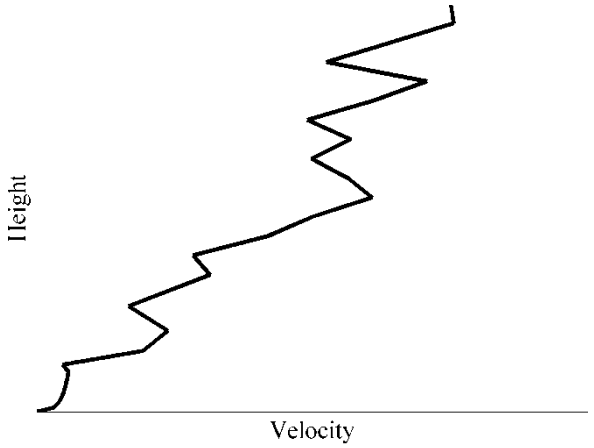


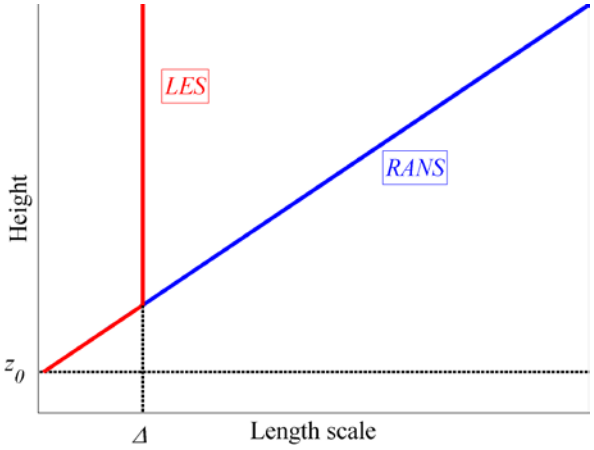


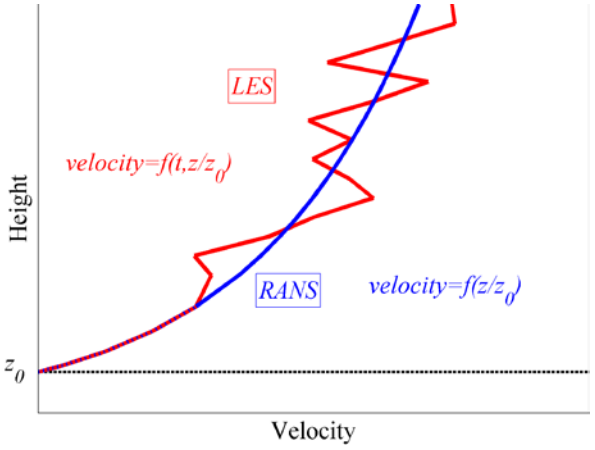


turbulence model, illustration









turbulence model, animation